

DRAFT SF 298

1. Report Date (dd-mm-yy)		2. Report Type		3. Dates covered (from... to)	
4. Title & subtitle Optimization and Prototyping of Medium Pressure Water (MPW) Depaint Process Tri-Service Committee on Corrosion Proceedings				5a. Contract or Grant #	
				5b. Program Element #	
6. Author(s) Mr. John Stropki Mrs. Robin Lee Stearns				5c. Project #	
				5d. Task #	
				5e. Work Unit #	
7. Performing Organization Name & Address				8. Performing Organization Report #	
9. Sponsoring/Monitoring Agency Name & Address Tri-Service Committee on Corrosion USAF WRIGHT-PATTERSON Air Force Base, Ohio 45433				10. Monitor Acronym	
				11. Monitor Report #	
12. Distribution/Availability Statement Approved for Public Release Distribution Unlimited					
13. Supplementary Notes					
14. Abstract					
15. Subject Terms Tri-Service Conference on Corrosion					
Security Classification of			19. Limitation of Abstract	20. # of Pages	21. Responsible Person (Name and Telephone #)
16. Report	17. Abstract	18. This Page			

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TRI-SERVICE CONFERENCE ON CORROSION



21-23 JUNE 1994

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Optimization and Prototyping of Medium Pressure Water (MPW) Depaint Process

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Introduction

This research program was designed to evaluate the potential of a paint stripping process that utilizes a medium pressure water jet as a viable alternative to the current practice of paint stripping and cleaning of aircraft with hazardous chemicals. The means of determining the viability of this environmentally safer blast process was predicated on establishing a set of process parameters at which paint stripping was accomplished at an economically sound rate, while minimizing any possible substrate damage.

A complete evaluation of the Aqua Miser® medium pressure water (MPW) blasting process and four candidate nozzles was conducted through three discrete tasks. Task 1 concentrated on (1) establishing depaint efficiency and (2) characterizing any potential substrate damage as a result of stripping with the MPW process. Tasks 2 and 3 included a field-level demonstration and evaluation of the Aqua Miser system on aircraft component parts and partial aircraft airframes, respectively.

A description of the technical activities and results obtained from each of the three tasks is provided in the following text.

Technical Approach

A summary of several OC-ALC requirements which are scheduled to be satisfied throughout the next 18 months includes:

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(1) MINI-LARPS (Large Aircraft Robotic Paint Stripping Facility)

- Installed and operational in Fall, 1994
- Use confined to depainting aircraft and component parts

(2) LARPS Facility

- Installed and operational in Spring, 1995
- "Full-scale" depainting of KC-135 and B-1 aircraft

(3) MPW Process

- Use confined to either touch-up or backup to LARPS on KC-135 and B-1 aircraft
- Use on B-52 and E-3 aircraft which cannot be depainted by LARPS because of facility limitations
- Full or partial depainting/cleaning of aircraft components.

Detailed descriptions of the various tasks conducted as a part of this study are provided in the following text.

Task No. 1. Optimization Testing of MPW Process

Task activities were divided into the following four subtasks: (1) Production Rate Assessment, (2) Qualitative Damage Assessment, (3) Spot Weld Integrity Assessment, and (4) Structural Vibration Stress Test. All four subtasks concentrated on determining the process parameters that produce the most efficient paint stripping rate with minimal blast imparted damage to common aluminum aircraft alloys. Production rates obtained during all optimization testing were determined by calculating the rate at which paint is removed from test panels with only water. Potential blast damage was determined by (1)

measuring any deformation which developed on the surfaces of small test coupons (arc height samples) after the paint removal operation, (2) characterizing the integrity of spot welds, and (3) measuring the stresses imposed on aluminum test panels that are configured to be representative of actual aircraft structures.

Production Rate Assessment

The type and dimensions of materials that were used to perform all optimization testing of the Aqua Miser water-only process with four (dual orifice, rotating head, fan, and LARPS) nozzles that were evaluated include:

- AL2024-T3 alclad - 0.032 inch by 24 inches by 24 inches.

Individual panels were coated with several "in-service" coating systems which included: polysulfide primer/polyurethane topcoat, Koroflex primer/polyurethane topcoat, self priming topcoat (SPT), solvent-based epoxy/polyurethane topcoat, and water-borne epoxy/polyurethane topcoat. The dry film thicknesses of most coatings ranged between 0.002 and 0.003 inches. Panels were cured for 7 days in a controlled laboratory environment that was maintained at 72 F and 50 percent relative humidity. All panels were then artificially aged in an oven at 210 F for 96 hours.

The process used for all optimization testing included a Government-furnished Model E25 Aqua Miser BOSS Blasting System that was manufactured by Carolina Equipment and Supply Company. By design, this electric unit is rated at 3.2 GPM @ 15,000 psi and capable of being adapted for use with the four different types of nozzles that were evaluated.

Control of the paint removal process on all test panels used for process optimization was achieved with a computer-controlled table assembly that was available at Tinker AFB. The horizontal axis of the table was capable of achieving speeds up to 4.0 inches per second and traveling approximately 24.0 inches in both directions. Individual test panels were mounted to the table and were positioned

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at a minimum distance of 2 inches and at a 60-degree angle from the blast nozzle.

Qualitative Damage Assessment

The type and dimensions of the Almen specimens used to determine the potential blast-induced damage to thin aluminum airframe materials included:

- A12024-T3 bare - 0.032 inch by 0.75 inch by 3 inches.

The 3-inch dimension of all specimens was oriented in the sheet rolling direction. In addition, all Almen specimens were sheared from painted panels. Blasting of individual specimens was on the common face of the original panel.

Panels from the individual Almen specimens were painted with each of the "in-service" coating systems and aged in accordance with the previously described procedures.

The protocol used to develop arc height data (blast-induced specimen deformation) included a quasisaturation blasting of the Almen specimens. Individual specimens were not repainted between the initial depainting cycle and after the subsequent four blast cycles. This form of testing represents a "worst-case" situation that may occur from either excessive dwell time during paint removal operations or the equivalent of an expected depainting cycle of Air Force aircraft.

The Almen specimen test fixture was mounted on the x-y table in a direction that ensured that the blast stream traversed the specimens perpendicular to the rolling direction of the Type 2024-T3 aluminum alloy. This alignment permitted full coverage of the test specimen with one pass of the blast stream. Final Δh measurements were made from Almen specimens that are blasted with the traversing direction perpendicular to the roll direction of the specimens. This was done to ensure that the Δh measurements were consistent with the procedures established by Battelle during previous Air Force paint removal programs.

Spot Weld Eddy Current Inspection Testing

Test panels for the spot weld integrity tests were prepared using two panel configurations: flat and 2-inch radius bend. Bends applied to the appropriate panels were applied prior to spot welding. Panels were constructed from the following materials and thicknesses:

- A12024-T3 alclad, 0.032 inch
- A12024-T3 alclad, 0.080 inch
- A17075-T6 alclad, 0.032 inch
- A17075-T6 alclad, 0.080 inch.

Fabrication and testing protocol for the various sets of metal test panels was in accordance with the OC-ALC LARPS Qualification Plan (paragraph 4.2.19).

The procedures used to conduct all spot weld eddy current inspections are as follows:

- Preparation of two (flat and 2-inch radius bend) panels for each of the four materials per LARPS Qualification Plan (paragraph 4.2.19).
- Establish baseline measurements by nondestructively eddy current inspecting every spot weld per T.O. IC-135-36.
- Blast panels with each of the four nozzles and optimized blast parameters that were obtained from testing performed in Subtasks 1 and 2. Two stripping cycles per panel.
- Nondestructively inspect every spot weld on stripped panels per T.O. IC-135-36.
- Compare all baseline measurements with post-stripping measurements to determine the location and frequency of broken spot welds.

The spot welding of all test panels was performed at OC-ALC. Additionally, all pre- and poststripping eddy current inspection testing was conducted by OC-ALC.

Structural Vibration Testing

A simulated aircraft fuselage section or test box was constructed to perform several stress tests during this subtask. The approximate dimensions of the box are 9 inches by 21 inches. As was discussed with OC-ALC/TIESM and OC-ALC/LAPEP personnel, the frame of the box was constructed from aluminum angles that are spaced to simulate the dimensions between ribs and stringers on an aircraft. Two different 8 inch by 8 inch test panels are scheduled to be evaluated on the frame. One panel is fabricated from 0.032-inch Type 7075-T6 bare aluminum sheet, and the second panel from 0.032-inch Type 2024-T3 bare aluminum sheet. Panels are to be secured to the angles with 0.0125-inch threaded fasteners, which are evenly spaced around the perimeter of the panel being evaluated. The strategic placement of several strain gages and an accelerometer onto the underside surfaces of the test panels permitted a recording of all stress and vibration measurements.

The intent of this test was to measure the induced strains and frequencies generated by the MPW process on a simulated aircraft fuselage section and assess the potential for fatigue damage.

Construction of the test box included the mechanical fastening of a single test panel to the aluminum frame. No sealant was used between the test panels and frame. Six strain gages were instrumented along the internal surfaces of each test panel. All components were secured and sealed to ensure maximum protection from potential water damage.

Stresses introduced onto the test panel as a result of the MPW process were measured by the strain gages at several intervals throughout the blasting process. Various combinations in nozzle stand-off distance, traverse rate, and blast jet rotational rate were investigated. The pressure of the water blast stream was maintained at approximately 15,000 psi. Testing did not include bicarbonate-of-soda media.

Task No. 2. Prototyping of MPW Process With BOSS Media on Aircraft Component Parts

Activities performed during this task concentrated on depainting aircraft component parts at Tinker AFB. Process parameters established for MPW and MPW plus bicarbonate-of-soda media blasting of the standard polyurethane coating system during testing conducted at WR-ALC and OC-ALC were used. All blasting operations were performed by OC-ALC personnel in Building 2122. This facility represented a production environment, therefore, was equipped with the power, air, water, and drainage requirements to complete this task. A summary of the activities performed, as well as the protocol for conducting this task, is provided in the following text.

The MPW plus media process was used to clean and/or depaint four (4) engine cowlings parts that were selected and removed from B-52 aircraft. All components were painted and heavily soiled with carbon residues and oil contaminants. Components had a metallurgical composition of either A12024 and A17075 and were classified MISTR (Maintenance Items Subject to Repair) parts that are authorized by OC-ALC to depaint with plastic media beads (PMB).

The Model E25 Aqua Miser unit used during the water-only optimization phase of Task I was used for blasting all painted component parts. However, a controlled rate of bicarbonate-of-soda media was introduced into the blast stream to increase depaint efficiency. Process efficiency was maximized by using the results of controlled testing that was performed on standard epoxy/polyurethane test panels that were depainted during Task I and at WR-ALC. The standard two-handed fan nozzle was the only nozzle that was to be used with the bicarbonate-of-soda media. Additional prototype testing with the LARPS mini-nozzle and water-only is also scheduled for depainting "select" airframe components.

Additional activities performed as part of this task included: (1) on-site technical assistance and/or training of OC-ALC production personnel responsible for operating and maintaining the MPW system, (2) measuring and documenting operational parameters which included safety and health-related hazards, and (3) an identification of all costs (shop floor time, man-hours, consumables, and equipment

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amortization) associated with the efficient operation of the Aqua Miser process. Process efficiency was determined by the production-level strip rates that were obtained at the initiation of this task.

Task No. 3. Prototyping of MPW Process on Partial Airframe Sections

Activities performed during this task focused on depainting Air Force designated airframe sections on large aircraft (KC/C-135 and B-52) that are maintained at Tinker AFB. Integration and testing of the optimized MPW process was conducted in conjunction with OC-ALC production personnel. Optimal blasting parameters established for a single nozzle that was selected during Task 1 was used in the testing conducted during this task.

On-site assistance was provided during the actual blasting operations that were performed by OC-ALC production personnel in a designated section of Building 2122 at Tinker AFB. Numerous aircraft depainting operations are performed in this facility; therefore, the basic (air, water, and electrical) requirements of the MPW system are available.

A summary of the activities that were performed, as well as the protocol for conducting this task, is provided in the following text.

Testing performed during this task is limited to the various aluminum (A12024, A17075 and A17079) airframe structures that are able to be depainted with the MPW process. OC-ALC/LAPEP stated that all depainting was to be performed on select areas (approximately 100 square feet) of structures on E-3 or B-52 aircraft. Possible areas included:

- top/bottom sides of wing
- fuselage (2 areas)
- vertical stabilizer
- engine nacelle.

OC-ALC personnel plan to provide Battelle with a mapping of the various coating systems applied to the structures that are to be

depainted. The majority of airframe structures are painted with the standard epoxy/polyurethane coating system. However, prototyping is to include a complete removal of the Koroflex primer/polyurethane coating system. No observable process-induced substrate damage is anticipated for these structures. Areas adjacent to the depainted structures are to be masked by OC-ALC personnel prior to testing.

Selective stripping of any non-standard coating systems that are on airframe structures are also scheduled to be investigated during this task. This stripping process involves the removal of only the outermost (topcoat) protective coating from the airframe structure. If proper techniques are used the primer on the structure will remain intact after being blasted with the medium pressure water.

The efficiency of the MPW process on aircraft structures is to be assessed by (1) determining the production strip rates for the various structures, and (2) visually characterizing the condition of the depainted structures.

All stripping parameters selected as a result of the testing performed during Task I are to be used to repaint approximately 1,000 square feet of select airframe structures. Carolina Equipment and Supply personnel were responsible for providing all services related to equipment set-up and the training of production personnel. On-site technical direction to OC-ALC production personnel was also provided to ensure that the optimized stripping parameters are maintained from structure to structure. This process summarized any problems that may develop in the production environment as a result of hardware limitations.

An additional aspect of this task will be to work closely with production personnel at Tinker to measure and document a final set of repainting parameters that maximizes the efficiency and safety of the MPW process.

Results

The results obtained from a limited amount of optimization and prototype testing that has been performed on each of the three tasks confirms that the water-only blasting process is capable of meeting

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the depaint production requirements of OC-ALC. Process capabilities that have been successfully demonstrated during Task I testing include (1) selective (topcoat only) and, (2) full depaint of "in-service" coating systems that are on OC-ALC aircraft. To date, all testing has been conducted on painted test panels with water-only blasting parameters. No bicarbonate-of-soda media was used on partial airframe test panels or sections of aircraft.

Optimization Testing

A total of four MPW blast nozzles were evaluated on 0.032-inch A12024-T3 alclad/bare panels. Included in the test matrix were panels coated with five different paint systems. A set of optimized blast parameters were obtained for each nozzle/coating system combination.

Results indicate that the highest production depaint rates and least damage on coated panels were obtained for the one-jet "hammerhead" or rotating nozzle and modified LARPS nozzles. Acceptance criteria for both nozzles were based on the quality of the surface finish for full and selective depainting with the MPW process.

The production rates and damage (Almen arc heights) measured for the various nozzles (selective and full depaint) are provided in Figures 1 and 2. As shown, no one nozzle will efficiently depaint all "in-service" coating systems. The highest selective depaint rates (1.1 to 2.3 ft²/min) were obtained for nozzles on the polysulfide/polyurethane coating system. Conversely, the LARPS, fan, and one-jet nozzles were the only nozzles capable of completely depainting all coating systems at an efficient (0.5 ft²/min) or acceptable rate. Disadvantages associated with the LARPS and fan nozzles, and related depaint parameters are the small standoff distances, narrow "footprints" and residues that remain on the surfaces of the aluminum panels coated with the Koroflex and polysulfide primers. These residues require a chemical (thinned version of SR-125A) clean-up prior to repaint processing. This clean-up is also required for the epoxy/polyurethane and Koroflex/polyurethane coatings that are removed with the one-jet or "hammerhead" rotating nozzle.

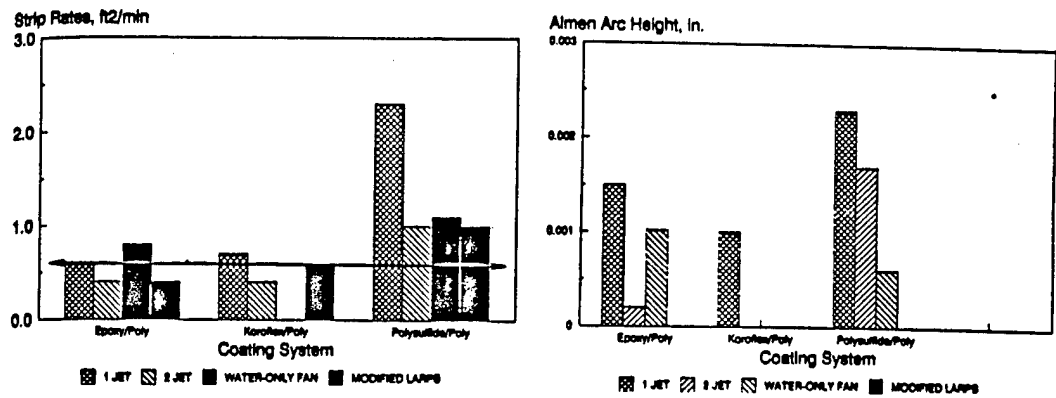


Figure 1. "Best" Selective Strip Processes

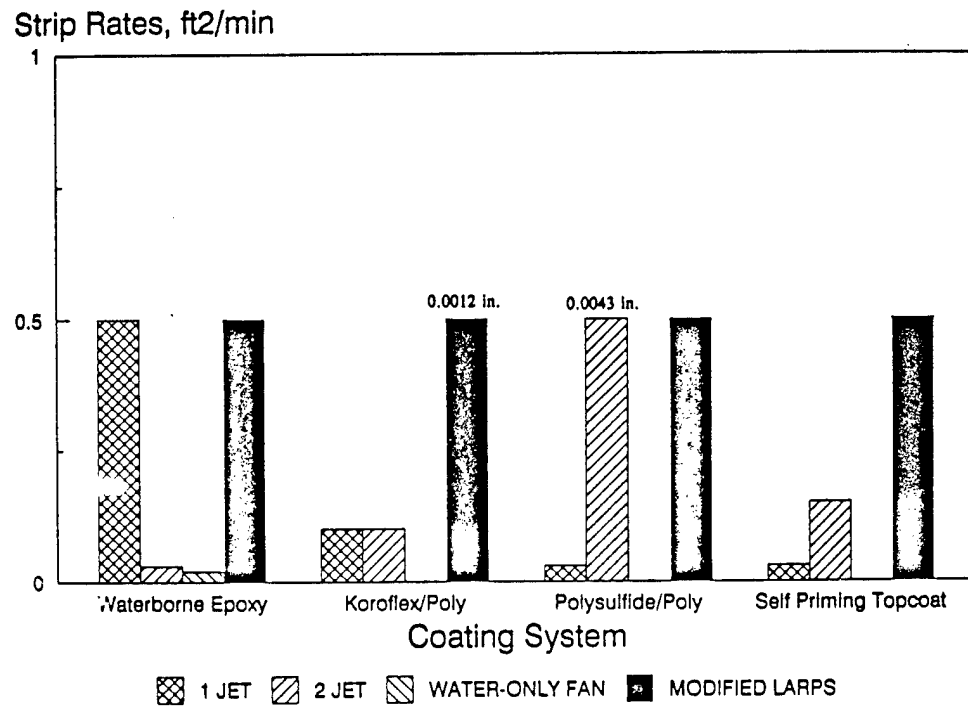


Figure 2. "Best" Full Strip Processes

All depaint parameters obtained for the LARPS and one-jet nozzles are to be used for component parts and partial airframe prototyping activities. Production rates on the "aged" Koroflex/polyurethane coating system of E-3 or B-52 aircrafts are scheduled to be obtained and compared to rates measured during laboratory testing. An assessment of the quality of the surface finish of the depainted airframe sections also will be performed and used to verify the production efficiency of the MPW-process. Final acceptance of the process will be based on the results obtained from the stress and spot-weld tests.

Stress and Spot-Weld Testing

To date, no results are available for these two tests as all testing has not yet been completed. Limited depainting of spot-weld panels has been performed and no damage or cracking has been measured for the examined spot welds. Testing included 2-pass processing with the dual-orifice nozzle on both flat and curved panels. Additional testing with each of the remaining three nozzles is required before a final set of results are provided to OA-ALC/LAP personnel.

Component Parts and Partial Airframe Prototyping

All prototyping activities are scheduled for completion during July, 1994. This particular task was intentionally delayed until the results of the stress and spot-weld tests are available. If the results of these tests indicate that the MPW process is a viable production tool, then the aircraft prototyping activities will be completed.

Preliminary cleaning and depainting of coating systems applied to the internal surfaces of B-52 engine cowlings have been completed. The results of these exercises have confirmed that the MPW process is capable of efficiently cleaning "baked on" carbon residues from the components. A post-blast examination of the depainted surfaces indicates that the process is acceptable and capable of providing a quick clean-up of these components. Additional cleaning and depainting of component parts is scheduled at OC-ALC. The results of these depaint exercises will be reviewed for input into the final report that is scheduled for issuance during September, 1994.